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Storage capacity analysis of Nipa Nipa regulation pond using Ripple method

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Abstract. Tallo River has the potential to pose a threat of flooding because it is strongly influenced tide. Regulation Ponds are flood control structures built upstream from areas that will be protected from flood hazards. Storage Capacity Analysis of Nipa regulation pond using Ripple method. Flood routing results obtained a maximum of 3.395.116,79 m³, while topographic conditions obtained a maximum of 3.583.270,96 m³ then optimization analysis based on the Ripple Method obtained with volume accommodated during 1980-1984 is 2.508.330,462 m³, during 1985- 1989 is 2.158.594,429 m³, during 1990-1994 is 1.721.928,984 m³, during 1995-1999 is 2.072.035,680 m³, the volume accommodated during 2000-2004 is 2.526.941,033 m³, volume accommodated during 2005-2009 is 1.996.205,351 m³ and volume accommodated during 2010-2014 is 1.913.798,405 m³. This shows that storage capacity of regulation Pond can serve to reduce flood in Tallo River. Based on the cumulative storage analysis, a maximum storage of 10.592.032,714 m³ obtained from the inflow and outflow analysis, indicating that the Nipa regulation pond was able to reduce flood in amount of 38,07 % i.e. 4.032.440,62 m³.

1. Introduction

Flood problems will attract attention after affecting human life and inflicting disaster/loss for communities around the river environment. Occurrence of flood can be distinguished by several kinds, namely the discharge too big or the capacity of the river is reduced. This can occur by natural symptoms or a consequence of the lack of liver activity of human activities in conducting the construction/management of rivers for various interests. In line with the pace of development of the community, especially those who live and do activities around the flood plains, the problems posed by flood, over time are increasing and need attention and efforts to overcome it well.

Flood is detrimental to the economic activity of society so it needs flood control [1]. Flood control is generally addressed by a sustained drainage system [2,3]. The sustainable drainage system is the management of drainage that starts from the utilization of rainwater, to collect and to store the run off and to throw away to deposit the sediment and the pollutant to adsorb it into the body of water [4].

Regulation pond is a means of flood control built in areas that are still empty or unproductive. Capacity of the regulation pond can be made in such a way that flood water flowing in the downstream



area does not exceed the existing capacity. With the development of the regulation pond is expected to reduce the peak of flood in order to be reduced to the flood overflow that is often occurred on river segment at the sand.

2. Research methodology

Location of this research was carried out in the Nipa Nipa Regulation Pond (119,52065923° EL ; 5,16503546° SL) Located in the Village of Moncongloe Lapara, District of Moncongloe, Maros Regency.



Figure 1. Research location map.

Reservoir storage capacity can be analyzed using several methods. But in this study Ripple method was used. This method was first proposed by Ripplé to calculate the amount of adequate reservoir capacity at a certain level of water demand [5]. Ripplé / Mass curve is a line that shows the flow rate at a certain time, assuming that when the cumulative draft is greater than the cumulative inflow, the reservoir cannot serve the needs [6]. Reservoir volume accumulation curve is a function of inflow discharge which is described with the equation:

$$Volume = \int Qdt = \sum Q(\Delta t) \tag{1}$$

Where : Qdt = Reservoir inflow, both as function of time

The following calculation procedure:

- Data Discharge is described as a mass of discharge lines (mass curve).
- Water requirement is considered constant, so the cumulative needs can be described with a certain tilt.
- Vertical distance between mass of discharge line with cumulative requirement line is capacity the largest vertical distance is the capacity required.

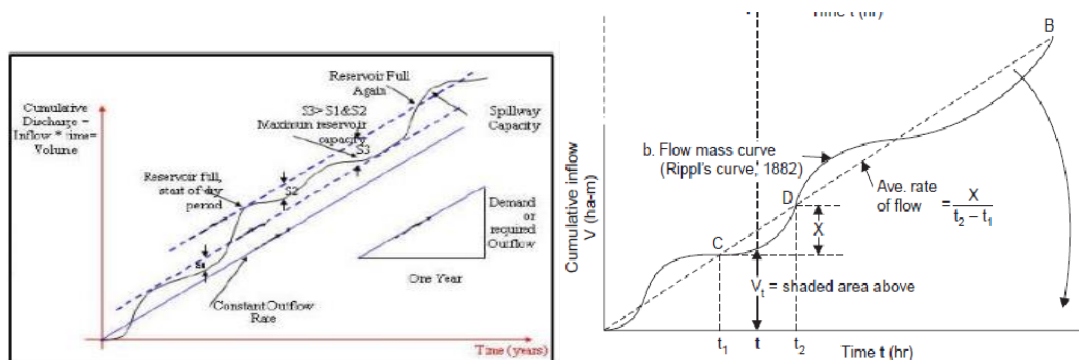


Figure 2. Ripplé mass curve.

Reservoir mass curve has many useful applications in the design of a storage capacity, such as determination of reservoir capacity, operations procedure and flood routing.

3. Results and discussion

Analysis Flood Routing is carried out to get the maximum flow that will enter the pond, taking into account the abundant discharge to the spillway building. The overflow discharge is calculated starting above the top height i.e. 5.61 m Table 2 column 1 is the height of the overflow building, while column 2 is the overflow height.

Table 1. Calculation of the relationship between overflow and basin height.

Elevation M	Head M	O m ³ /s	A m ²	S m ³	S m ³ /s	α2 m ³ /s
1,25	0,00	0,00	28885,91	-	0,000	0,00
2,25	1,00	289,00	764265,26	396.575,59	110,160	509,32
4,75	3,50	1892,34	813151,00	1.874.019,20	520,561	2933,47
5,61	4,36	2631,04	834606,00	2.660.589,91	739,053	4109,15
7,38	6,13	4386,20	848195,11	4.032.440,62	1120,122	6626,45

From the calculations in Table 1 it can be seen that the maximum storage is 4.032.440,62 m³ at an elevation of 7,38 m.

Table 2. Calculation of inflow and outflow Q₂₀.

T Hour	I m ³ /s	Q m ³ /s	t Hour	I m ³ /s	Q m ³ /s	t Hour	I m ³ /s	Q m ³ /s
0	4,909	4,909	17	222,306	282,907	34	54,111	80,732
1	7,905	5,089	18	200,230	264,907	35	50,979	76,431
2	21,502	10,111	19	181,327	241,037	36	48,046	72,566
3	51,413	28,241	20	164,980	220,594	37	45,300	68,910
4	102,572	42,299	21	150,742	202,826	38	42,729	65,451
5	179,491	68,648	22	138,497	187,246	39	40,321	62,178
6	286,395	90,112	23	127,280	173,605	40	38,067	59,081
7	427,006	124,498	24	117,005	161,419	41	35,956	56,150
8	470,352	175,881	25	107,593	150,139	42	33,980	53,376
9	483,002	220,806	26	98,971	139,694	43	32,129	50,751
10	473,163	260,371	27	91,073	130,018	44	30,396	48,266
11	448,222	304,631	28	82,006	121,050	45	28,774	45,914
12	412,801	331,052	29	75,808	111,873	46	27,254	43,687
13	367,411	343,317	30	70,421	103,190	47	25,832	41,580
14	324,521	337,221	31	65,634	96,618	48	24,500	39,585
15	285,497	327,145	32	61,337	90,786	49	23,253	37,697
16	248,572	304,770	33	57,456	85,522	50	22,085	35,910

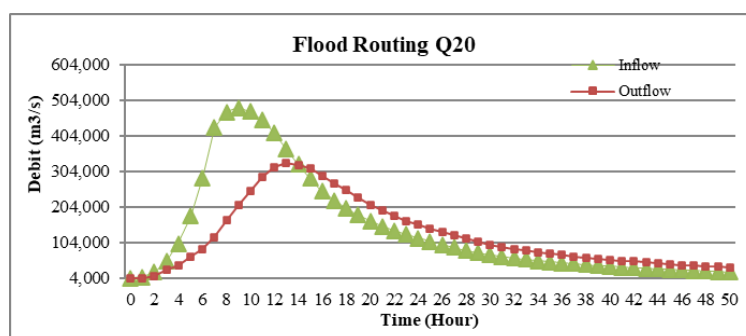


Figure 3. Flood routing.

The maximum flow of inflow into the pool is 483,002 m³/s while the outflow through the spillway is 327,080 m³/s then produces a graph like the one above which shows that the regulation pond capacity planning can be used to reduce the peak of flood that occurs in the Nipa-Nipa Regulation Pond.

Based on contour drawings and layout plans, the pond volume calculation is done using the truncated pyramid method [7,8].

Table 3. Calculation of slides based on topography.

Elevation (m)	Height Difference (m)	Area (m ²)	Volume (m ³)	Cumulative Volume (m ³)
1,25		28.885,91		0,00
	1,00		396.575,58	
2,25		764.265,26		396.575,58
	2,50		1.971.770,32	
4,75		813.151,00		2.368.345,90
	0,86		708.535,51	
5,61		834.606,00		3.076.881,41
	1,77		1.489.278,98	
7,38		848.195,11		4.566.160,40

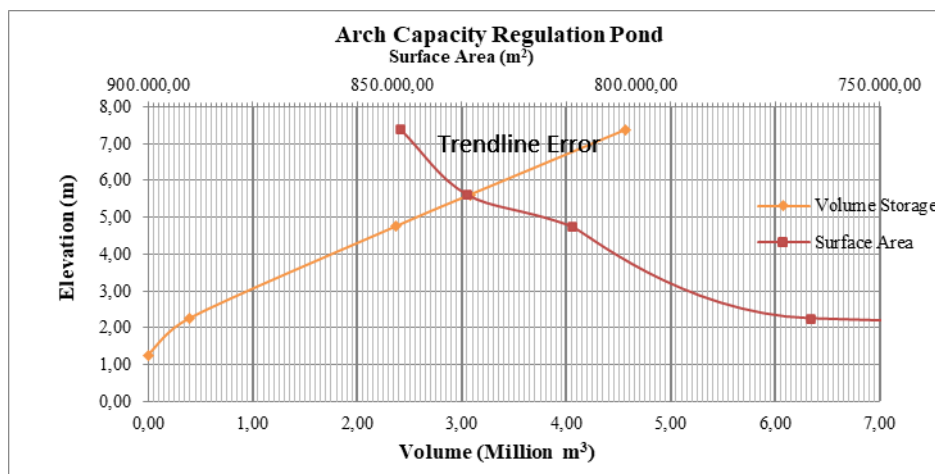


Figure 4. Curved capacity of nipa nipa regulation pond.

The maximum reservoir height is at an altitude of 7,38 m where the surface area of the reservoir is 848.195,11 m² and the maximum storage capacity is 4.566.160,40 m³.

The mass curve is a curve that is used for the purposes of initial reservoir design and to see reservoir performance after it is operated. The Ripple diagram can be used as a tool to determine targeted benefits and the effective storage capacity needed [9,10]. The principle is that the reservoir serves to collect water during the rainy season.

Figure 5 shows that if the end points of the mass curve are connected by a straight line AB, the slope represents the average discharge from the flow during the total period during which the mass curve has been plotted. Reservoir to allow the release of water continuously at the average value of discharge for the entire period, the capacity required for the reservoir is represented by a vertical intercept between two straight lines A'B' and A''B'' drawn parallel to AB and the tangent line to the mass curve at the lowest tangent C and the highest tangent D respectively. The reservoir is full at D and will be empty at C and the full reservoir at points E, F and I, between points G and H there will be water spills from the reservoir. Based on Figure 5, it can be seen that volume can be known water flowing during t = t₀ to t = t₁ (y₀ to y₁) is 2,693,267,986 m³. And the volume that was accommodated during 1980-1985 was 2,508,330,462 m³.

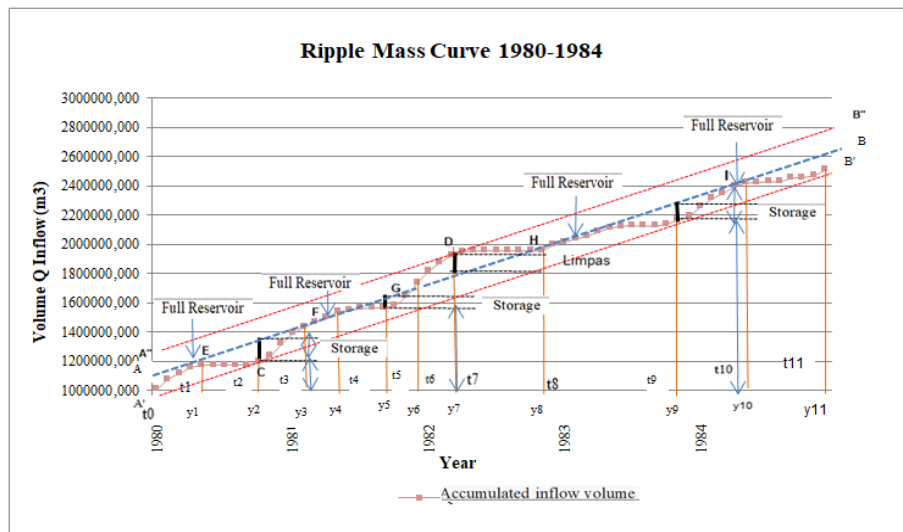


Figure 5. Mass curve 1980-1984.

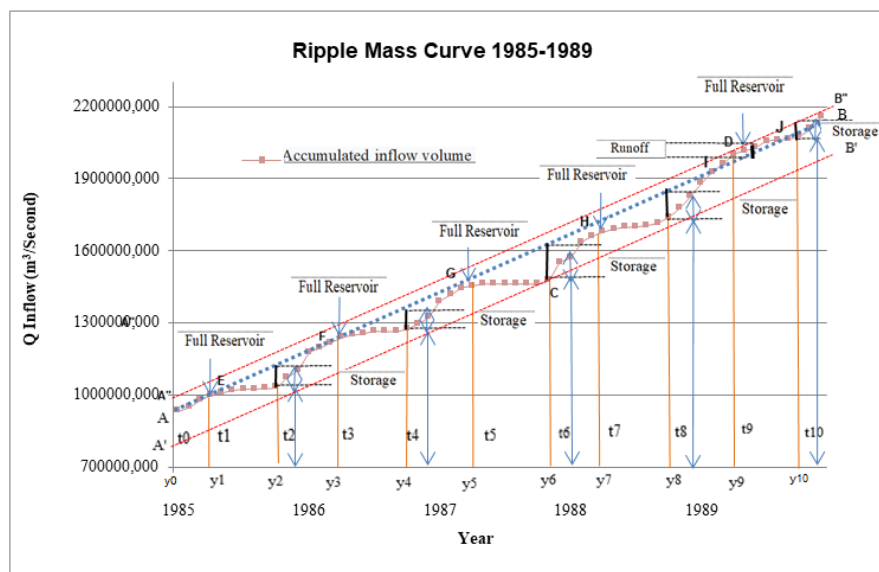


Figure 6. Mass curve 1985-1989.

Figure 6 shows that if the end points of the mass curve are connected by a straight line AB, the slope represents the average discharge from the flow during the total period in which the mass curve has been plotted. reservoir to allow the release of water continuously at the average discharge value for the entire period, the capacity required for the reservoir is represented by a vertical intercept between two straight lines A'B' and A''B'' drawn parallel to AB and the tangent line to the mass curve at the lowest tangent C and the highest tangent D respectively. The reservoir is full at D and will be empty at C and the full reservoir at points E, F, and G, between points I and J there will be water spills from the reservoir. Figure 6 shows the volume flowing that it can be seen the volume of water flowing during $t = t_0$ to $T = T_{10}$ (Y_0 to Y_{10}) is $2,158,594,429 \text{ m}^3$. And the volume that is accommodated during 1980-1985 is $2,158,594,429 \text{ m}^3$.

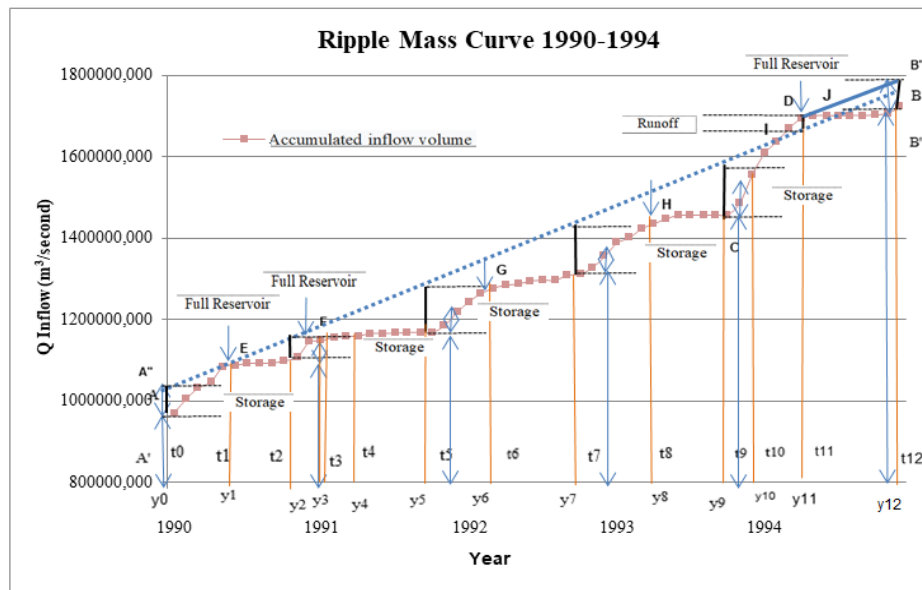


Figure 7. Mass Curve 1990-1994.

Figure 7 shows that if the end points of the mass curve are connected by a straight line AB, the slope represents the average discharge from the flow during the total period in which the mass curve has been plotted. reservoir to allow the release of water continuously at the average discharge value for the entire period, the capacity required for the reservoir is represented by a vertical intercept between two straight lines A'B' and A''B'' drawn parallel to AB and the tangent line to the mass curve at the lowest tangent C and the highest tangent D respectively. The reservoir is full at D and will be empty at C and the full reservoir at points E and F, between points I and J there will be water spills from the reservoir.

Figure 7, it appears that it can be known that the volume of water flowing during $t = t_0$ to $T = Q_{12}$ (y_0 to Y_{12}) is $1,721,928.984 \text{ m}^3$. And the volume that was displayed during the year 1990-1994 is $1,721,928.984 \text{ m}^3$.

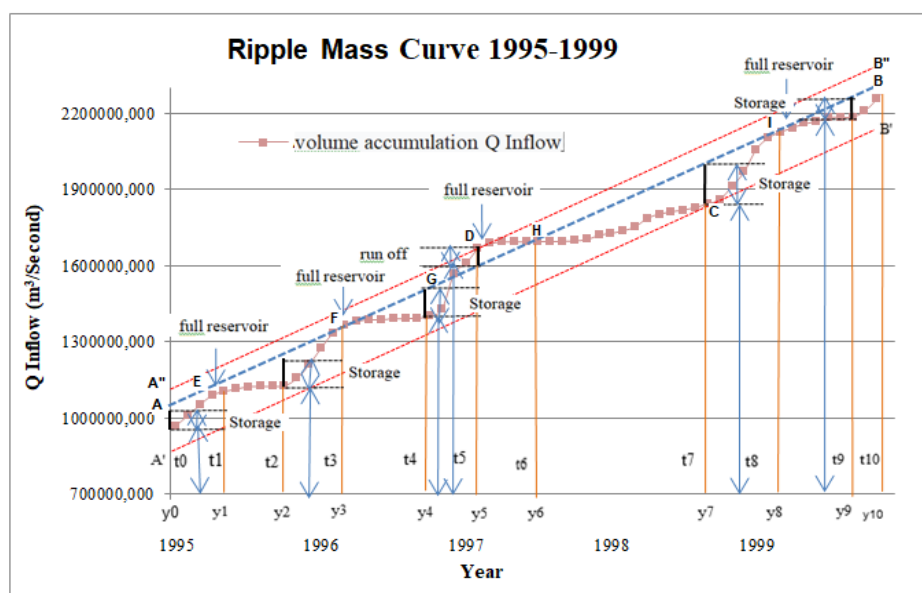


Figure 8. Mass Curve 1995-1999.

Figure 8 shows if the end points of the mass curve are connected by a straight line AB, the slope represents the average flowrate of the flow during the total period in which the mass curve has been plotted. If the reservoir is to be built to allow the release of water continuously at the average discharge value for the whole period then the capacity required for the reservoir is represented by a vertical intercept between two straight lines A 'B' and A "B" drawn parallel to AB and tangents to mass curve at the lowest tangent C and the highest tangent D respectively. If the reservoir that has this capacity contains the same volume of water as AA 'at the beginning of the period, the reservoir will be full at D and will be empty at C and the full reservoir at points E, F and I, and between points G and H there will be water spills from the reservoir. Figure 8, it appears that the volume of water flowing during $t = t_0$ to $T = T_{10}$ (y_0 to Y_{10}) is $2,326,132.084 \text{ m}^3$. And the volume that was displayed during the year 1995-1999 is $2,072,035.680 \text{ m}^3$.

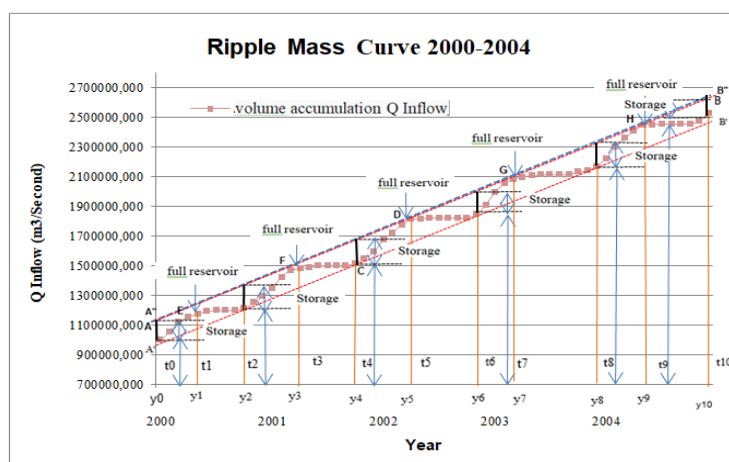


Figure 9. Mass curve 2000-2004.

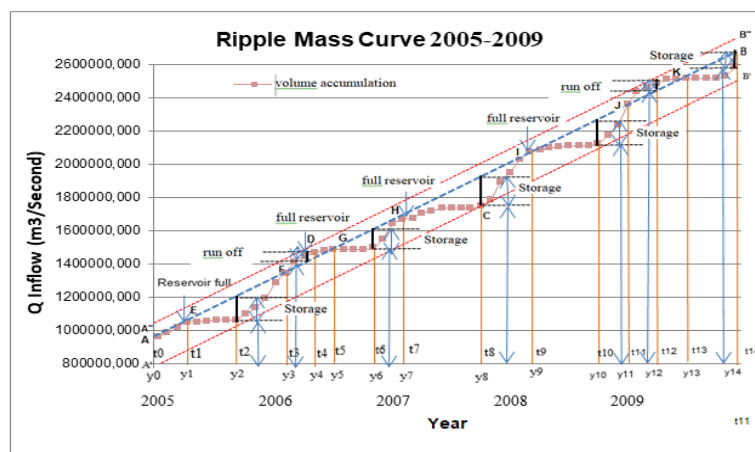


Figure 10. Mass curve 2005-2009.

Figure 9 shows that if the end points of the mass curve are connected by a straight line AB, the slope represents the average discharge from the flow during the total period during which the mass curve has been plotted. If the reservoir is to be built to allow the release of water continuously at the average discharge value for the whole period then the capacity required for the reservoir is represented by a vertical intercept between two straight lines A 'B' and A "B" drawn parallel to AB and tangents to mass curve at the lowest tangent C and the highest tangent D respectively. If the reservoir that has this capacity

contains the same volume of water as AA 'at the beginning of the period, the reservoir will be full at D and will be empty at C and the full reservoir at points F, G and H in this period will not experience water spills. Figure 9, unknown volume of water flowing during $t = t_0$ to $T = T_{10}$ (y_0 to Y_{10}) is $2,526,941.033 \text{ m}^3$. And the volume that was displayed during the year 1990-1994 is $2,526,941.033 \text{ m}^3$.

Figure 10 shows that if the end points of the mass curve are connected by a straight line AB, the slope represents the average discharge from the flow during the total period during which the mass curve has been plotted. reservoir to allow the release of water continuously at the average discharge value for the entire period then the capacity required for the tangent reservoir to the mass curve at the lowest tangent C and the highest tangent D respectively. The reservoir is full at D and will be empty at C and the full reservoir at points E, H and I, between points F and G there will be water spills from the reservoir as well as between points J and K. In Figure 10 can be known the volume of water flowing during $t = t_0$ to $T = t_{14}$ (y_0 to Y_{14}) is $2,590,093.931 \text{ m}^3$. And the volume that was displayed during the year 2005-2009 is $1,996,205.351 \text{ m}^3$.

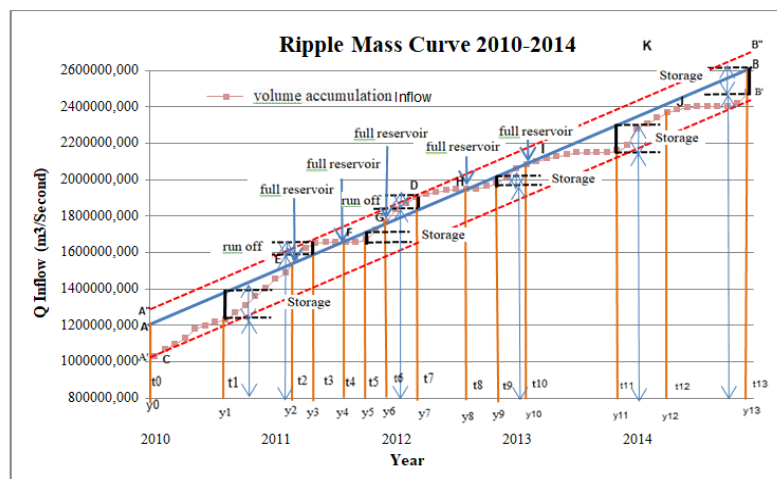


Figure 11. Mass curve 2010-2014.

Figure 11 shows if the end points of the mass curve are connected by a straight line AB, then the slope represents the average flowrate of the flow during the total period in which the mass curve has been plotted. reservoir to allow the release of water continuously at the average discharge value for the entire period, the capacity required for the reservoir is represented by a vertical intercept between two straight lines A'B' and A''B'' drawn parallel to AB and the tangent line to the mass curve at the lowest tangent C and the highest tangent D respectively. The reservoir is full at D and will be empty at C and the full reservoir at point I, between points E and F there will be water spills from the reservoir as well as between points G and H. In Figure 11 can be known the volume of water flowing during $t = t_0$ to $T = t_{13}$ (y_0 to Y_{13}) is $2.482.642,818 \text{ m}^3$. And the volume that was displayed during the year 2010-2014 is $1.913.798,405 \text{ m}^3$.

Based on the cumulative storage analysis, a maximum storage of $10.592.032,174 \text{ m}^3$ obtained from the inflow and outflow analysis, indicating that the Nipa Nipa regulation pond was able to reduce flood in the amount of 38,07 % that is $4.032.440,62 \text{ m}^3$.

4. Conclusion

- Based on the analysis results obtained a maximum storage of $3,395,116.79$ at an elevation of $7,38 \text{ m}$.
- Based on topographic conditions, the maximum height of the reservoir is at an elevation of 6.25 m where the surface area of the reservoir is $848.195,11 \text{ m}^2$ and the maximum storage capacity is $4.566.160,40 \text{ m}^3$.

- Based on the evaluation using the Ripple Method, the volume collected during 1980-1985 is 2.508.330,462 m³, during 1985-1989 is 2.158.594,429 m³, during 1990-1994 is 1.721.928,984 m³, during 1995-1999 is 2.072.035,680 m³, the volume accommodated during 2000-2004 is 2.526.941,033 m³, the volume accommodated during 2005-2009 is 1.996.205,351 m³ and the volume accommodated during 2010-2014 is 1.913.798,405 m³ indicating that the Nipa Nipa Regulation Pond could reduce flood in Tallo River. Based on the cumulative storage reservoir of 10.592.032,174 m³ obtained from the inflow and outflow analysis, it shows that the Nipa Nipa regulation pond is able to reduce flood by 38,07 % that is 4.032.440,62 m³.

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